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At the request of SNRA personnel, Boise Field Office Forest Health Protection (FHP) personnel have been applying the mountain pine beetle antiaggregant verbenone to lodgepole trees among campgrounds and administrative areas around Little Redfish and Redfish Lakes from 2000-2003. The enclosed report (BFO-PR-04-02) summarizes the results of the verbenone trial over the past 4 years.

Please contact Rob Progar or Dayle Bennett if you need additional information or assistance.

/s/ Dayle D. Bennett (for)
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Enclosure

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2000-2003 REDFISH LAKE VERBENONE TRIAL
Progress Report, October 2003

BFO-PR-04-02

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Abstract

Mountain pine beetle, *Dendroctonus ponderosae* is the most common cause of mortality of mature lodgepole pine (*Pinus contorta* var. *latifolia*). In 2000-2003, the antiaggregative compound verbenone was applied annually to the same lodgepole pine stands in campgrounds and resort facilities at the Sawtooth National Recreation Area (SNRA) in central Idaho to assess its ability in deterring mountain pine beetle attack through the course of a multi-year outbreak. Verbenone was applied at the rate of 40 5g pouches/acre releasing 25-35 mg/24h at 20°C. Significantly fewer trees were attacked and killed in the verbenone plots during 2000 and 2001. However, of the plots containing verbenone, a higher percentage of large trees were attacked in the second year of treatment, suggesting the efficacy of verbenone may diminish under increasing beetle pressure. In 2002 and 2003, there were nearly twice as many trees attacked and killed in the verbenone plots as in the untreated plots. It is hypothesized that the change in the performance of verbenone may be due to the large beetle population overwhelming the treatment.

Introduction

The mountain pine beetle (MPB), *Dendroctonus ponderosae* is considered the primary cause of mortality of mature lodgepole pine (*Pinus contorta* var *latifolia* (Cole et al. 1985). Tree losses associated with outbreaks of MPB have been described as devastating (Safranyik 1988), exceeding a million trees a year in some forests (Klein et al. 1978), causing changes in density, stand age, and species composition. MPB also causes serious mortality in ponderosa pine (*Pinus. ponderosa*), western white pine (*P. monticola*), and whitebark pine (*P. albicaulis*) (Amman and Cole 1983). Trees from 4-5 inches in diameter at breast height (d.b.h.) and greater are susceptible to attack by mountain pine beetle (Furniss and Carolin 1977).

TheSNRA is the most popular recreation area in central Idaho. The region contains the headwaters of the Salmon River, over 300 lakes, and is characterized by a high elevation (> 6,000 feet) alpine climate. One of the prime attractions of the area is the Redfish Lake Recreation complex with its campgrounds, lodge, and resort facilities.

Lodgepole pine is the dominant tree species in the SNRA. A significant percent of the pine is mature (> 8 inches d.b.h.) and at risk of beetle attack. Over the past several years, the building MPB population has caused tree mortality that severely impact the ambiance and esthetic integrity of the recreation area.

Current practices to lessen the severity of an MPB epidemic on lodgepole pine rely heavily on stand manipulation (Amman and Baker 1972, Amman et al. 1991), the use of attractive pheromones, or the application of prophylactic chemical insecticides. The insecticide carbaryl has been applied to campground trees to protect them from beetle attack (Gibson 1982). However, trees immediately adjacent to natural bodies of water cannot be chemically treated because of the unacceptable risk of aquatic contamination resulting from spray drift or leaching. To attempt to deter beetle attacks within this sensitive area, the experimental antiaggregative compound verbenone was placed among lakeside trees in 2000-2003.

Verbenone is the principal antiaggregative pheromone component of MPB and was first isolated and identified by Pittman et al. (1969). The semiochemical has been shown to reduce the incidence of successful MPB attacks on lodgepole pine (Schmitz 1988, Lindgren et al. 1989, Amman et al. 1991, Shea et al. 1992, Amman and Ryan 1994, Miller et al. 1995). Other authors did not find significant differences between verbenone and untreated plots (Amman et al. 1989) or reported encouraging early results but later experiments yielded ambiguous data (Amman and Lindgren 1995). Verbenone is effective in suppressing the aggregation of male and female southern pine beetles (SPB) (*Dendroctonus frontalis*) (Billings et al. 1995) and was registered for SPB suppression in 1999. This study was initiated to assess the efficacy of verbenone in deterring MPB attack in high value trees in campgrounds in sensitive riparian habitats through the course of a multi-year outbreak.

Another semiochemical is the antiaggregant pheromone MCH (3-methyl-2-cyclohexen-1-one) and has been shown to reduce attacks by over 90 percent on Douglas-fir (*Pseudotsuga menziesii*) by the Douglas-fir beetle (*Dendroctonus pseudotsugae*). MCH was registered in 1999 and is being used to operationally suppress this important pest. Trials of MCH have also been conducted to suppress spruce beetle (*Dendroctonus rufipennis*). However, results have been inconsistent and inconclusive. An excellent review of the literature on MCH can be found in Zogas et al. (2001).

Methods

In June 2000, 16 one-half acre rectangular (210 x 105 ft) plots were located in and around campgrounds and adjacent visitor facilities (44°09’ N 114°54’ W) in mature lodgepole pine stands along the shoreline of Little Redfish and Redfish lakes in the SNRA. The species and d.b.h. were recorded for each plot tree. In 2002, several of the plots were compromised by management activities and were dropped from the study.

The pheromone formulation consisted of 98 percent technical grade, 80 percent (-), 20 percent (+) verbenone (4,6,6-trimethylbicyclo[3.1.1]-hept-3-en-2-one). The verbenone was formulated by and purchased from Phero Tech, Inc., Delta, British Columbia, Canada, and applied at the rate of 40 5g pouches/ac. This study used more verbenone (5g pouches) with a higher rate of release (25-35 mg/day at 20°C) over prior studies of verbenone on MPB. On July 5, 2000, June 14, 2001, June 12, 2002, and June 17, 2003, verbenone pouches were placed on the north-facing side of the same 20 trees in each of eight randomly selected plots at a height of 12 feet and a spacing of one pouch every 32 feet or one pouch/1000 feet. The eight remaining untreated plots were used for comparison. Since the effective duration of elution from the verbenone pouch was considered to be 140-200 days at 20°C, the entire span of time over which MPB emerged and took flight should be encompassed. At the SNRA, the majority of MPB beetle flight is usually concentrated in a 2-week period during July. However, sufficient numbers emerge from June through September to warrant extended coverage. During October 2000, September 2001, October 2002, and September 2003, current-year beetle attacks were recorded and evaluated. One-way ANOVA (Sokal and Rohlf 1981) was used to compare the impacts of MPB on lodgepole pine between treatments. Treatments were considered significant at $P \leq 0.05$. SAS JMP software (SAS 2001) was used for all analyses by ANOVA.

Results and Discussion

Pretreatment analysis of host tree dbh showed no significant difference in the numbers of trees within size class between plots receiving verbenone and those in the untreated check (Figure 1).

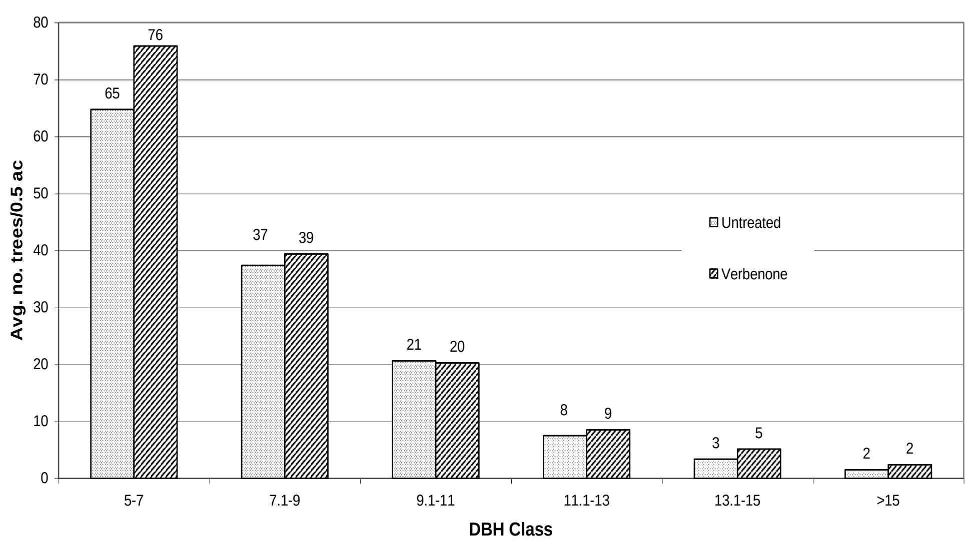

Figure 1. Average per plot density of susceptible lodgepole pine between treatments by d.b.h.

In 2000, treatment comparison of MPB attacks indicated significantly more lodgepole pines were attacked on the untreated plots than on plots containing the verbenone pouches (F = 6.9; df = 1, 14; P = 0.02). The mean number of successfully attacked lodgepole pine per plot was 16.5 (SE = 5.28) for untreated plots and 2.37 (SE = 1.03) in plots containing verbenone pouches (Figure 2).

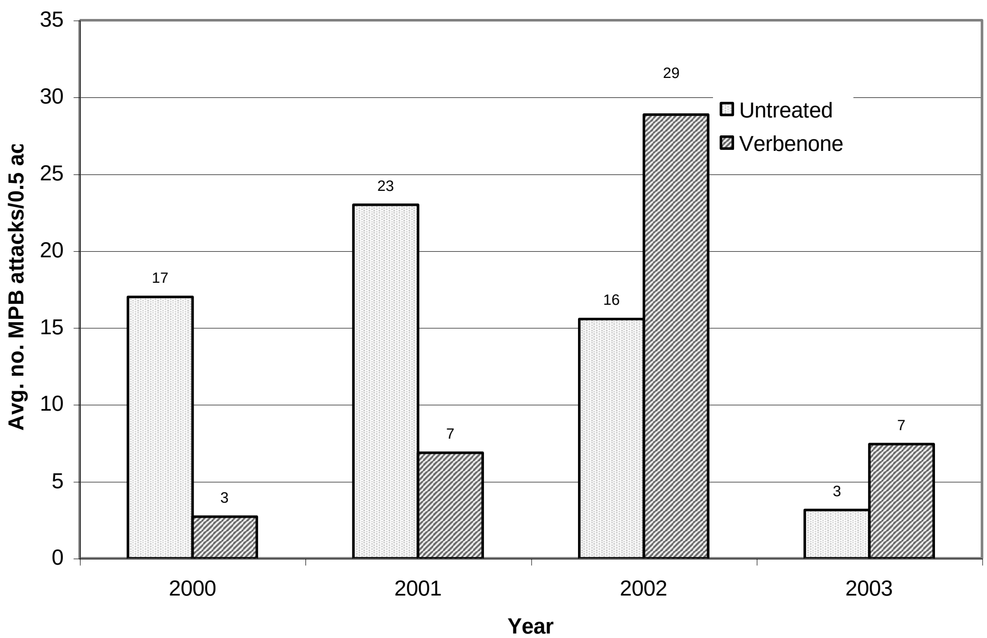

Figure 2. Average number of successful MPB attacks/plot during 2000-2003.

In 2001, the number of beetle killed trees increased by 39 percent to an average of 23 trees (SE = 3.64) per untreated plot and by nearly 200 percent to an average of seven trees (SE = 2.80) killed by beetles in the verbenone-treated plots. The increase in the incidence of successful attack on trees in treated plots may indicate a threshold level of beetle abundance in response to verbenone. Although more trees were killed by MPB in verbenone-treated plots in 2001 than in 2000, there were significantly fewer (F = 13.1; df = 1, 14; P = 0.003) beetle killed trees in the plots containing verbenone than in untreated plots (Figure 2). In 2002, there were an average of 29 MPB killed trees (SE = 9.21) in the verbenone plots and 16 killed trees (SE = 4.99) in the untreated plots. However, differences in the number of MPB killed trees between the treatments were not significant (F = 1.61; df = 1, 12; P = 0.229). This event was surprising because of the successful performance of verbenone in deterring MPB attack over the past 2 years. In 2003, there were more than twice as many trees killed by MPB in the verbenone (mean = 7.42, SE = 2.22) treated plots than in the untreated plots (mean = 3.14, SE = 1.29), however the difference was not significant (P = 0.12).

Several hypotheses have evolved to describe the year-to-year inconsistency of the performance of verbenone in suppressing MPB attacks on lodgepole pine: (1) the population of beetles becomes so large that they overwhelm the verbenone signal; (2) MPB undergoes a physiological change that alters their response to verbenone; and (3) the verbenone eluted from the pouches before beetle emergence and flight had ended.

The urgency of the beetles to find suitable host trees may overwhelm the verbenone signal. Because attacks occur simultaneously on many trees, the likelihood of beetles landing on trees that have been previously attacked (or trees with verbenone) increases and leads to a higher probability of successful attacks (Amman and Lindgren 1995).

A similar response was encountered in trials of verbenone in central Idaho in the early 1990's (Amman et al. 1991); several years of satisfactory results were followed by a poor response to the antiaggregant. Results by Rasmussen (Amman and Lindgren 1995) suggest that since the large suitable host trees are killed by MPB attack in previous years, only small diameter host trees are available in the current year. In the small trees larval survival is lower (Cole et al. 1976), and adult beetles take longer to develop and are smaller in size (Amman and Cole 1983). Amman and Lindgren (1995) note that beetles developing from the thin phloem of small diameter trees tend to ignore the verbenone signal. Hence, as the population of host trees decrease to a diameter where beetle survival becomes marginal, the surviving beetles may either not respond to the verbenone signal or respond in a different manner. As a result of the shift in beetle response, trees in the plots containing verbenone may become susceptible to MPB attack and be killed.

There is the possibility the verbenone may have eluted from the pouches before beetle emergence and flight ended for the year. The span of time that MPB emerged at the SNRA varies with trap location and between years. In 2000, the span of emergence as measured by Lindgren funnel traps occurred from early July through late August and peaked on July 18 (B. Bentz unpublished data). In 2001, the period of emergence spanned from early July through mid-September with peaks occurring in mid-July and late August to early September (B. Bentz unpublished data, S. Munson, S. Seybold, and D. Ross unpublished data). In 2002, MPB emergence at Redfish Lake peaked during the third week of July (B. Bentz unpublished data). Although the rate of elution is defined as 25mg/day at 20°C on the product label, the rate can vary with weather and temperature. For SPB, the expected lifespan of a verbenone pouch is 25-40 days in the southern United States (Phero Tech Product # RD-0372/000 label). In the high elevations of central Idaho where the high temperature averages in the upper 70's during July-August and the low temperature averages in the upper 30's for the same period, the elution of verbenone was expected to include the entire MPB flight.

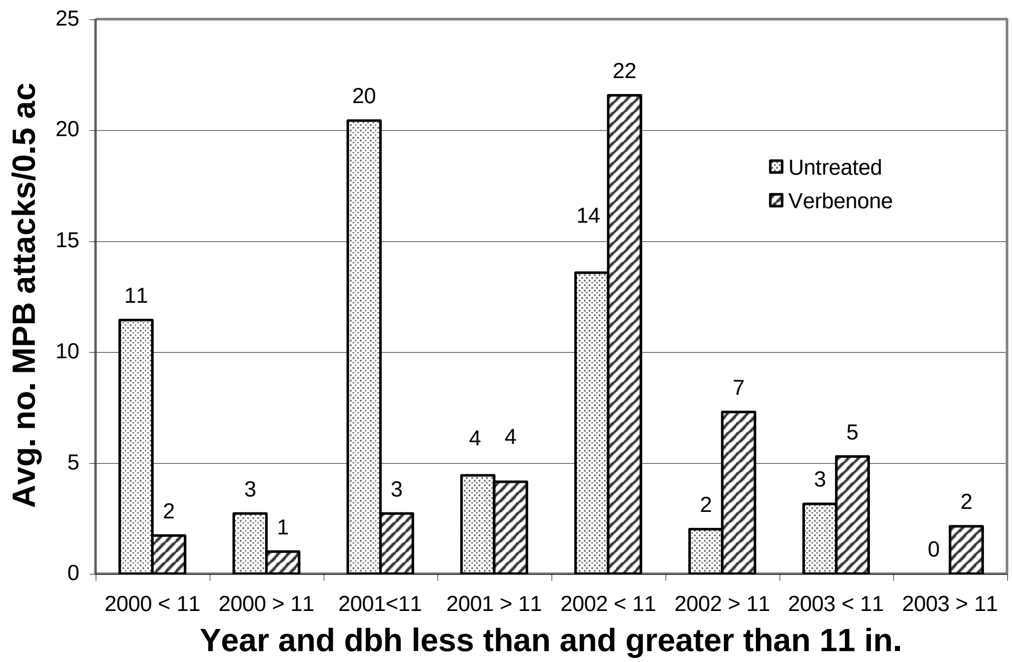

Figure 3. Comparison of MPB attacks over the duration of the outbreak by small and large d.b.h.

Examination of treatment differences by tree d.b.h. (Figures 3 and 4) showed significantly greater numbers of beetle-killed trees < 11 inches d.b.h. in untreated plots than in verbenone-treated plots during 2000 and 2001. However, in each of these years, there was no significant difference in the number of successful beetle attacks on trees > 11 inches d.b.h. between verbenone-treated and untreated plots. In 2000, an average of 3.5 (SE = 1.4) trees > 11 inches d.b.h. were successfully attacked and killed on the untreated plots whereas 0.87 (SE = 0.4) were killed on plots containing verbenone pouches (trees < 11 inches: d.b.h.: $F = 8.05$; df = 1, 14; $P = 0.01$; trees > 11 inches: $F = 3.09$; df = 1, 14; $P = 0.10$). In 2001, there was an average of four trees (SE = 1.8) > 11 inches d.b.h. that were successfully attacked on the untreated plots and 3.87 (SE = 1.6) trees on the verbenone-treated plots (trees < 11 inches d.b.h.: $F = 25.63$; df = 1, 14; $P = 0.0002$; trees > 11 inches d.b.h.: $F = 0.002$; df = 1, 14; $P = 0.95$). Lack of significant differences during 2000-2001 between treatments among trees > 11 inches d.b.h. may indicate a decreasing efficacy of verbenone on larger trees under conditions of increasing beetle pressure or may be attributed to the small plot size used in this study.

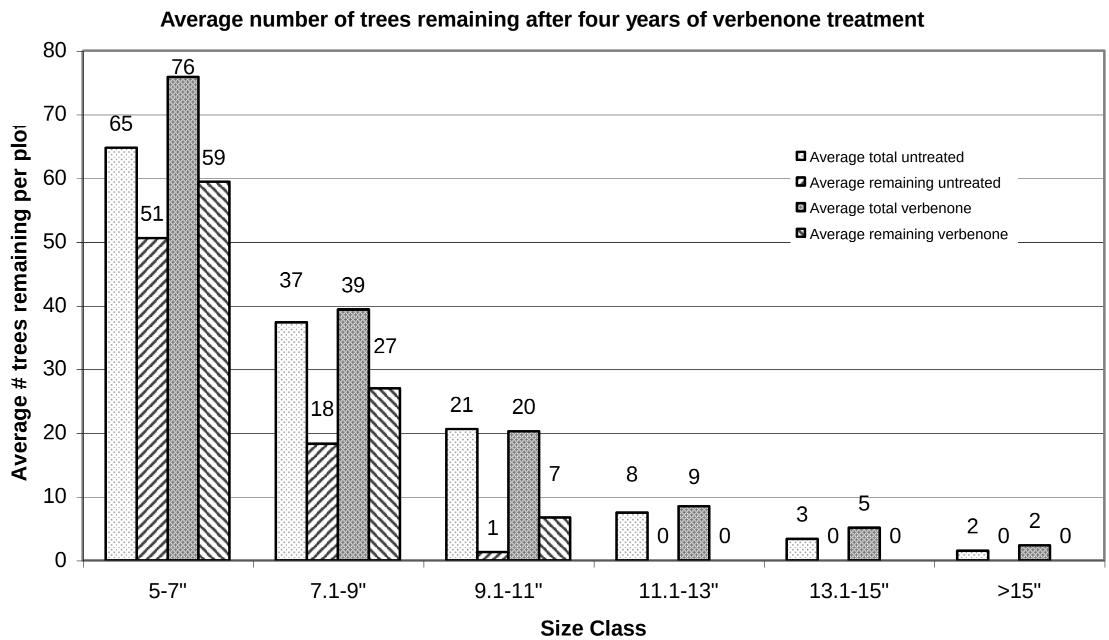

Figure 4. Average number of trees remaining by d.b.h. size class after 4 years by treatment and d.b.h.

In 2002, the differences in the number of trees attacked and killed by MPB between treatments approached significance with an average of 7.3 (SE = 2.5) trees > 11 inches d.b.h. attacked and killed on plots containing verbenone and 2.0 (SE = 0.9) trees > 11 inches d.b.h. on the untreated plots (trees > 11 inches d.b.h.: F = 3.86; df = 1, 12; P = 0.07). Figure 4 shows that after 3 years, few trees > 11 inches d.b.h. remain on either the untreated plots or the plots containing verbenone. There was an average of 22 MPB killed trees < 11 inches d.b.h. on the verbenone treated plots and 14 trees killed on the untreated plots (trees < 11 inches d.b.h.: F = 0.9; df = 1, 12; P = 0.36). After the2003 MPB attacks, there are no trees greater than 11 inches d.b.h. remaining on the plots. Approximately one-third of the trees in the 9-11-inch size class remain in the verbenone treated plots and average of a single tree in this size class remains on the untreated plots.

Shea (1992) noted there were high numbers of unsuccessfully attacked trees (pitchouts) in plots treated with verbenone when compared with untreated plots. There were no significant differences in the number of pitchouts between treatments during 2000 and 2001 (yr 2000: F = 1.03; df = 1, 14; P = 0.33; yr 2001: F = 0.07; df = 1, 14; P = 0.788). However, in 2002, there were nearly twice as many pitchouts in the verbenone treated plots ($\bar{x}$ = 8.28, SE = 1.61) than in the untreated plots ($\bar{x}$ = 4.42, SE = 0.84) (F = 4.49; df = 1, 12; P = 0.05). This response may be related to plot size and to beetle density and become more pronounced with larger study plots and increasing beetle abundance. In 2003, there were more pitchouts in the verbenone treated plots (8.3 vs. 5.3) but the difference was not significant.

There were significantly higher numbers of strip attacks among untreated plots in 2000 (0 = 5.62, SE = 5.15) than in the plots containing verbenone (0 = 1, SE = 0.59) (F = 5.81; df = 1, 14; P = 0.03). The number of strip attacks in untreated (0 = 3.75, SE = 0.61) vs. verbenone (0 = 2.37, SE = 0.59) plots was not significantly different in 2001 (F = 2.55; df = 1, 14; P = 0.13). In 2002, there were more strip attacks occurring in the verbenone plots (0 = 14.14, SE = 3.39) than in the untreated plots (0 = 10.71, SE = 5.12), however, the difference was not significant (F = 0.77; df = 1, 12; P = 0.39). In 2003, there were significantly (F = 2.93; df = 1, 12; P = 0.03) more strip attacks in the verbenone treated plots (0 = 7, SE =1.97) than the untreated plots (0 = 1.85, SE = 0.67).

Individual trees containing pouches within the verbenone plots showed the same evidence of beetle attack as trees that did not contain pouches, although in general, significantly fewer attacks occurred on verbenone-treated plots. There was no observable effect of individual tree protection conferred by the verbenone pouch on a tree. However, there was only a single verbenone pouch placed on each treated tree, and recommendations for SPB include up to nine verbenone pouches per tree for exclusion (Phero Tech Product # RD-0372/000 label). This area of research needs to be explored for mountain pine beetle to determine if there may be a dose response for individual trees.

Mountain pine beetle populations continue to build at the Redfish Lake Recreational Complex (Thier, 3420 letter, dated February 6, 2001 to Forest Supervisor Sawtooth NF.). In 2003-2004, we plan to continue the current study to assess the ability of verbenone to deter MPB attack on the same susceptible lodgepole pine stands for the duration of an outbreak. As the beetle outbreak expands throughout the SNRA area, fewer unattacked trees will be available, thus increasing pressure on trees within the verbenone plots. Future studies should include a sufficient number of trees with a d.b.h. > 11 inches d.b.h. to adequately evaluate the relationship of verbenone and MPB in larger size-classed trees. Also, the relationship between verbenone and beetle density needs to be resolved before verbenone can be considered an operational tool for protection from attack by MPB.

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